THE AFFECT OF LAND USE AND LAND COVER ON WATER QUALITY IN URBAN ENVIRONMENTS

Natural Resources and Environmental Sciences (NRES)

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Abstract

Students of Kansas State University's Natural Resource and Environmental Sciences Capstone course conducted basic surface water tests on Little Kitten Creek watershed in Manhattan, Kansas and compared it to samples collected at Kings Creek on the Konza Prairie for the purpose of determining relationships between land use land cover and water quality. We hypothesized an inverse relationship between land use land cover and water quality metrics. Water quality parameters were measured using a HACH® test kit. Relationships were compared on a subwatershed scale for Little Kitten Creek and watershed scale for Little Kitten Creek and Kings Creek. The Little Kitten Creek watershed was broken down into three subwatersheds: Vanesta, Kimball, and Anderson. The northernmost site (Vanesta) was the least developed, containing mostly grassland. The central site (Kimball) was mostly residential. The southernmost test site (Anderson), also the outlet of the watershed, was mostly urban developments. Little Kitten Creek watershed land use and land cover was categorized as Developed, Grassland Herbaceous, and Deciduous Forest for analysis, while Kings Creek watershed was categorized as Developed Open Space, Grassland Herbaceous, and Forest. Relationships were compared on subwatershed and watershed scales.

Water quality test parameters include dissolved oxygen, phosphorus, nitrogen, electrical conductivity and pH. Data was imported into an ArcGIS program to build upon a citizen science project initiated by the Fall 2014 NRES capstone class with the purpose of demonstrating that non-expert citizens could contribute to studies of watershed quality.

The test results showed that the water quality metrics in the Little Kitten Creek watershed differed from the Kings Creek watershed, particularly in phosphorus, dissolved oxygen, and electrical conductivity. Based on results, it was concluded that urban development has an impact on surface water quality. More frequent surface water tests should be performed throughout the year, with more kits and volunteers (citizen scientists) to develop a thorough analysis.

Introduction

Citizen science is the use of non-expert citizens in the collection of data for scientific analysis. Citizen science is gaining popularity in the scientific community and can be used to provide large data sets. In our experiment, we took water quality samples using a HACH® Test Kit, a relatively simple kit allowing tests to be performed by non-expert citizens. The HACH® Test Kit was used to measure phosphorus (P), nitrogen (N), dissolved oxygen (DO), electrical conductivity (EC), turbidity, pH, water temperature and air temperature. These measurements are common water quality indicators and can be used to assess the effectiveness of a watershed for filtering runoff.

The primary purposes of our study was to determine the impacts of land use and land cover on the quality of surface waters while developing the Citizen Science Water Quality Mapping project begun by the Fall 2013 Natural Resources and Environmental Sciences Capstone class by adding our data to the Adobe Flex-based Web mapping application they created (Grant, et al. 2013). This is an important relationship to establish because of our societal dependence on surface waters for drinking, recreation, household use, and irrigation. By establishing relationships between land use, land cover and water quality, we can develop recommendations for watershed management to better protect our surface waters from pollution. By taking water quality samples in areas with varying amounts of urbanization and comparing them to surface waters surrounded by natural vegetation, we evaluated the impact of land use and land cover on the water quality metrics.

We hypothesized that as urban land increases within the watershed, surface water quality would decline. Declines in water quality are predicted to be shown by increased nitrogen (N), phosphorus (P), turbidity and electric conductivity (EC) while showing decreased dissolved oxygen (DO) and pH. No significant difference in water temperature was expected across varying land use and land cover gradients.

Literature Review

Citizen Science

Citizen Science and Water Quality Testing

Citizen science has been used effectively for many years in various scientific research studies. Many companies and educational institutions are now starting to use this method of massive collection of data and observations to draw conclusions which aid in effective widespread research.

Urban water quality in ditches, streams, retaining ponds and other landscaped environments are not often studied and could have great impacts on the health and beauty of communities. By using citizen scientists to take water samples and report visual clues, more knowledge about urban open water systems and their locations related to the type of land use can help shine light on areas of poor water quality and potential health threats. Addressing these issues will improve urban health and safety for birds, mammals, reptiles and human neighbors. Citizens of communities will have a part in changing their surroundings for the betterment of all.

Definition of Citizen Science

Citizen science is the use of volunteer, and often minimally trained, scientists to assist paid researchers in gathering information and observations on a wide-scale.

The term “citizen scientists” refers to volunteers who participate as field assistants in scientific studies. Citizen scientists help monitor wild animals and plants or other environmental markers, but they are not paid for their assistance, nor are they necessarily even scientists. Most are amateurs who volunteer to assist ecological research because they love the outdoors or are concerned about environmental trends and problems and want to do something about them. Typically, volunteers do not analyze data or write scientific papers, but they are essential to gathering the information on which studies are based (Cohn 2008, 192).

Working with citizen scientists is hardly new. In 1874, the British government funded the Transit of Venus project to measure the Earth’s distance to the Sun,(Dickinson, Zuckerberg, and Bonter 2010, 149) and the National Audubon Society's annual Christmas bird count, which began in 1900. About 60,000 to 80,000 volunteers now participate in that survey (Cohn 2008, 192).

Cornell’s Lab of Ornithology has been using citizen science to collect bird population data through internet programs such as their website www.eBird.org. Participants make observations of birds they see; common and uncommon and tally them on a list kept on ebird.org (Cornell Lab of Ornithology; Audubon 2014). Researchers then use the cumulative data from the nationwide participants and gain valuable knowledge of bird behavior, such as migration and nesting habits (Sullivan 2009).

Ornithology is not the only way citizen science can be used to help researchers, but it certainly has the most following and successful history to take lessons from.

Challenges and Benefits of Citizen Science

Just like many other methods of research, there are concerns regarding accuracy when using citizen science. An early concern regarding citizen science data was observer quality, that is, skill of participants compared to professional biologists. Like ecological field assistants, citizen scientists vary in ability, experience, and type of training. Training deficits may certainly lead to increased error or bias, but it is not yet clear whether allowing citizen scientists to teach themselves how to follow protocols, as is typical for internet-based projects, is less effective than personalized training (Dickinson, Zuckerberg, and Bonter 2010, 149).

Use of citizen science is growing and it will be of great benefit for further studies to take place to determine areas where errors could occur. Physical limitations, bias, proper training for the project, age and skill requirements are all considerations that should be taken into account when acknowledging the data collected.

One concern with accuracy may be from over-worked volunteers, or volunteers who have become bored. Designing your research with bias in mind and trying to anticipate how volunteers may inadvertently alter data due to certain conditions, like weather, location, ease of access, and ease of collection process, among other factors, is an important part of the process.

The benefits of citizen science for both the researchers and volunteers are numerous. For volunteers, participation gives them a sense of involvement, contributes to lifelong learning, and in many cases it gets them outside and moving. Many of the participants are already hobbyists in the field they are helping collect data. For example, someone who already enjoys bird-watching and is fairly good at identifying bird species, can simply take the extra step of contributing their observations. Participants who hike on a regular basis can also make basic observations or collect specimens they see on their walks.

The benefits for researchers are incredible. Researchers can gather terrific amounts of data over great distances that normally would be impossible, or very time-consuming to conduct themselves. By using volunteer scientists, a great deal of money can be saved in the research process as well, especially if training requirements are minimal on behalf of the paid staff.

Donald Owen, an environmental protection specialist with the National Park Service (NPS) in Harper's Ferry, West Virginia, said speaking of professionals, “We can't get enough research assistants to do what we can get volunteers to do. Not even close. The Appalachian Trail was built and is still maintained by volunteers. Using volunteers is the way the world works on the trail.” Using volunteers also allows scientists to gather data on a larger geographic scale and over a longer time period than is possible in more traditional scientific research (Cohn 2008, 192).

The advantage to data collected by citizen scientists over “expert” scientists is that citizens have a local and very personal knowledge of the area in which the tests are done. They may be able to identify problem areas before a professional would know to test there (Ottinger 2010, 244).

Many citizen-science projects have received funding because of their ability to connect authentic scientific research with science education. A critical component of this effort is the creation of educational materials, including background information that allows participants to understand the theory and ideas behind the research, a comprehensible description of the research questions, and clearly described, tested protocols for how to carry out observations. For all project types, the potential educational benefits range from acquiring skills needed to collect data accurately to critical scientific thinking and inquiry, in which participants apply knowledge to generate new questions and then design studies or develop models to answer those questions (Dickinson et al. 2012, 291).

Citizen Science Program Model

The Cornell Lab of Ornithology's model for developing and implementing a citizen science project has been developed over time by a group of individuals with expertise in education, population biology, conservation biology, information science, computational statistics, and program evaluation. They have found that projects whose developers follow this model can simultaneously fulfill their goals of recruitment, research, conservation, and education” (Bonney et al. 2009, 977).

The Cornell Lab's model for developing a citizen science project is as follows:

1. Choose a scientific question.
2. Form a scientist/educator/technologist/evaluator team.
3. Develop, test, and refine protocols, data forms, and educational support materials.
4. Recruit participants.
5. Train participants.

Citizen Science Going Forward

For the continuation of the long term study of watershed health, students as young as 4th grade could easily take on the task of testing water samples using the HACH® kit. The Watershed Quality Research in the future would benefit by having more sampling data gathered. With limited researchers, using the assistance of the public could amplify the data gathered tremendously.

Residential areas should be considered ecosystems and citizen science should be used to study the impact of human behavior and human urban land use to encourage better choices in the community. Urban and residential areas have unique biological aspects and management requirements. They are comprised of residents both human and nonhuman living in small scale areas and interacting with each other.

How humans design and then maintain residential areas play a part in the ecological health of the area. By involving citizens in the research to determine where issues may lie, those same citizens become agents of change (Cooper et al. 2007, 11).

Although human capacity to change the environment is responsible for accelerated losses of ecosystem attributes and functions, ironically, this capacity to implement change can also be tapped to address conservation problems in residential landscapes. Residential areas offer a large, capable, and mostly untapped workforce that can assist in developing and tackling scientific questions and implementing, and subsequently monitoring, outcomes of management strategies at a scale impossible to achieve in a landscape not addressed by more traditional approaches to habitat restoration (Cooper et al. 2007, 11).

In order to be successful and accurate, planning and design are important to any citizen science project. The study of urban water quality could successfully be conducted by volunteer citizens who live and work in the very neighborhoods being tested. By training volunteers and distributing equipment, water samples could be collected and read and reported back to researchers to culminate the results into useful information that could help planners develop better infrastructure. This should benefit the researchers and the volunteers alike. With proper supervision and planning, citizen science is a useful tool when considering ecological improvements in urban settings.

Relationships between Water Quality and Anthropogenic Stresses

Rising populations in urban areas place significant stress on water quality and availability. As people move into an area, new support facilities are needed such as roads, housing, shopping and commercial facilities. Land is disturbed during such construction, which can affect water quality. Increased human activity raises the likelihood of increased contaminants in the water supply. Rural land use, such as agriculture, can also affect water quality. Agricultural runoff into streams and watersheds can actually make rural streams more toxic than those in urban areas.

In a global assessment of ecological and toxicological effects generated by inorganic nitrogen pollution in aquatic ecosystems, three major environmental problems were discovered. “(1) It can increase the concentration of hydrogen ions in freshwater ecosystems without much acid-neutralizing capacity, resulting in acidification of those systems. (2) It can stimulate or enhance the development, maintenance and proliferation of primary producers, resulting in eutrophication of aquatic ecosystems. (3) It can reach toxic levels that impair the ability of aquatic animals to survive, grow and reproduce. Inorganic nitrogen pollution of ground and surface waters can also induce adverse effects on human health and economy” (Camargo, Alvaro 2006). These three problems can be simplified to the fact that through nitrogen pollution of our aquatic ecosystem we face acidification, eutrophication and unfixable toxicity in our water supply. These irreversible effects can harm us through consumption, and also through our food supply.

Water and other resources must be used in the most sustainable ways possible to protect our ecosystems. Education of citizens is also critical to improve water quality and maintain water resources. People living in a specific region must understand the needs of an ecoregion in order to promote water quality and conservation.

Land Use Land Cover (LULC) and Water Quality Metrics

Land use and land cover have long been known to have effects on surface and groundwater quality. Land use refers to the type of human activity that occurs on the land. Land cover is the amount of vegetative cover on the surface of the land. Land cover varies seasonally in natural and agricultural lands as plant life cycles progress. In urban land, land cover is extremely limited because of concrete, asphalt and buildings covering the land’s surface.

Surface waters have natural sediment and nutrients deposited in them from the land by natural processes. However, as land use and land cover changes mostly from human development, land can provide excessive levels of nutrients and sediment to surface waters (Banner, Stahl & Dodds, 2009; Nelson & Booth, 2002; Van Drecht et al., 2003; Zaimes, Schulte & Isenhart, 2004; Tong & Chen, 2002; Brabec, Schulte & Richards, 2002). Human development includes agricultural operations, forestry, and expanding cities and towns. The majority of nutrients and sediment deposited in surface waters is a result of soil erosion (Banner, Stahl & Dodds, 2009; Van Drecht et al., 2003). When the soil is left bare, rainfall and wind transport soil particles and nutrients into surface waters. In combination with soil erosion, the addition of nutrients from urban lawn fertilizers, agricultural fertilizers, nitrogen fixing legumes, and manure all increase the amount of nutrients in our soils (Pierzynski, Sims & Vance, 2000). This increase in soil nutrient levels makes the land more susceptible to nutrient deposition in surface waters. Our surface waters provide irrigation, drinking water, and recreation areas all of which can be compromised by excessive nutrients and sediments being deposited in them. This paper serves as a summary of the effects of land use and land cover on various water quality metrics of surface waters including phosphorus, nitrogen, pH, electrical conductivity, and turbidity.

Phosphorus (P)

Agricultural development and urban development are responsible for a large amount of phosphorus loading in surface waters (Griffith et al., 2002; Banner, Stahl & Dodds, 2009; Tong & Chen, 2002). In agricultural lands, tillage and plowing leaves the soil exposed to rain and wind which erode the soil and transport nutrients and sediment to the surface waters in runoff. In urban land, lawn fertilizers high in P may run off into streams. The lack of vegetative cover means that nutrients in runoff reach impervious surfaces rapidly where they are often transported to surface waters (Brabec, Schulte, & Richards, 2002). In addition, synthetic fertilizers used in urban and agricultural areas are transported off of fields or through groundwater by leaching and can then be transferred to surface waters via groundwater transport (Pitt, Clark & Field, 2009; Hayashi & Rosenberry, 2001). Phosphorus levels in urban areas were also found to be significantly higher than natural lands (Banner, Stahl & Dodds, 2009). This is likely due to over application of lawn fertilizers which are typically higher in P content than is necessary. This is an easily remediated issue as it just requires education of urban landowners.

Nitrogen (N)

Nitrogen is typically transported to surface waters through leaching to groundwater and subsequent transfer to surface waters by groundwater surface water interfaces (Pitt, Clark & Field, 2009; Hayashi & Rosenberry, 2001). Nitrogen can also be transported to surface waters by being carried in soluble forms in runoff or by direct deposition from animals (Van Drecht et al., 2003). In addition, the over-application of N fertilizers can lead to denitrification which in turn leads to atmospheric deposition of nitrogen in surface waters (Pitt, Clark & Fields, 2009). In a study by Van Drecht, a model was developed to measure non-point source pollution of streams with nitrate. In the Mississippi river, it is estimated that 89% of nitrate nitrogen levels come from agricultural practices. Worldwide it is estimated that around 67% of total N deposits in surface waters are caused by agricultural practices (Van Drecht et al., 2003).

Electrical Conductivity (EC)

Electrical conductivity is a measure of the salt content of water. It is an important measurement for irrigation water as saline irrigation water can lead to saline soil conditions (Pierzynski, Vance & Sims, 2000). In agricultural settings, the EC of surface waters was found to be significantly higher than that of surface waters with natural vegetation or urban land surrounding them (Tong & Chen, 2002).

pH

As a measure of a solution's acidity, pH has a significant impact on aquatic organisms and can harm species composition as well as biodiversity. In one study, pH was found to increase significantly in surface waters adjacent to agricultural lands as compared to urban and natural lands (Tong & Chen, 2002). In the same study, there was no significant difference found between the pH levels of surface waters where the adjacent landscape was characterized as urban land or natural land (Tong & Chen, 2002).

Soil water quality indicators, including nitrogen, phosphorus, electrical conductivity, turbidity (sedimentation), and pH, are all agreed to be affected by increasing the amount of urban development and agricultural development. Nitrogen, phosphorus, electrical conductivity, and turbidity all saw increases in areas with increasing urban and agricultural lands. These effects are likely tied to the reduced amount and consistency of land cover as well as the addition of nutrients from fertilizers, manure, and nitrogen fixing legumes.

Paired Watershed Analysis

Water quality analysis is typically performed for a specific watershed, or an area of land where all of the water that is under it or drains off of it goes into the same place (EPA 2014). In a paired watershed analysis, two sites are selected: the area of interest and an area of control. In the case of assessing LULC on water quality, a developed urban or agricultural area would be compared to the closest watershed with primarily natural land cover. This allows changes in pre and post development to be assessed in an area without actually gathering the data prior to development. The assumption is that minimal change in water quality would occur between the two sites without development (Bishop, et. al., 2005).

Paired watershed analysis was used to assess the effectiveness of agricultural BMPs in reducing P concentrations of New York's Cannonsville Reservoir. The paired watershed analysis used the farm watershed as the area of interest and a forested watershed as the control. Streamflow and water quality data were continuously monitored at the outflow of each watershed for two years pre-treatment and four years post treatment (Bishop, et. al., 2005).

Methods

Study Sites

Using a paired watershed analysis approach, Little Kitten Creek watershed was selected as the area of interest. Located in the northwest corner of Manhattan and extending just outside the city's limits, it receives an annual precipitation of 762.0mm (Choodegowda, Malinga and Kedarnath 2014). For this study, it was broken into three subwatersheds: Vanesta, Kimball, and Anderson with areas of 167.5 hectares, 74.5 hectares, and 57.9 hectares (see Fig. 1). The limits defined in this analysis provide a total area of 300 hectares; however, data was collected at overpasses where Little Kitten Creek intersects Vanesta Drive, Kimball Avenue, and Anderson Avenue. The outlet of the watershed is at the confluence of Little Kitten Creek and Wildcat Creek, just after Anderson Avenue. As such, the actual size is slightly greater than 300 hectares.

The land cover categories it is comprised of include Open Water, Developed Open Space, Developed Low Intensity, Developed Medium Intensity, Developed High Intensity, Deciduous Forest, Grassland/Herbaceous, and Woody Wetlands.

Figure 1: Little Kitten Creek Subwatersheds and Test Point Locations

Kings Creek, located south of Manhattan in the Konza Prairie, was selected as the control (Fig. 2). The watershed it lies within spans an area of 1581 hectares. The Konza Prairie is a protected site with land cover categories of Grassland Herbaceous, Developed Open Space, Emergent Herbaceous, Mixed Forest, Deciduous Forest, and Woody Wetlands. Data was collected at coordinates 39.11 and -96.61.

All watersheds and subwatersheds were delineated using ArcGIS software. A tool was created that determines the geographic region contributing to a given point by taking into account flow direction and accumulation for that point. The digital elevation model (DEM) was acquired by the National Elevation Dataset (NED). National Land Cover Database 2011 (NLCD 2011) provided the land cover layer used in analysis with 10m x10m resolution. Attribute tables for watershed shapefiles were used to quantify land coverage and watershed data. LULC information came from Multi-Resolution Land Characteristics Consortium (MLRC).

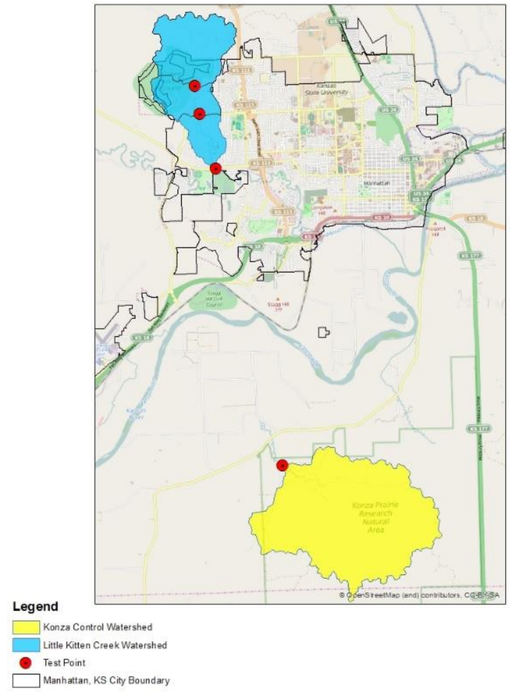

Figure 2: Kings Creek Watershed and Test Point Location with Respect to Little Kitten Watershed and Test Points

Land Use and Land Cover

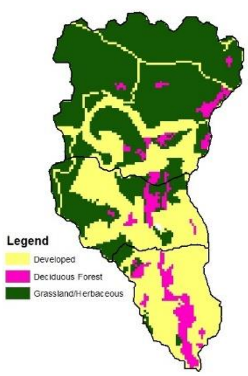

Figure 3: Little Kitten Creek LULC

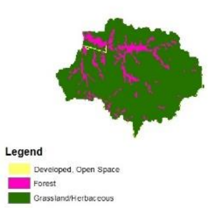

Figure 4: Kings Creek LULC

The LULC categories Developed Open Space, Developed Low Intensity, Developed Medium Intensity, and Developed High Intensity were combined into a “Developed” category. Woody Wetland was combined with Forest. Using these categories, the watershed is comprised of 40% Developed land, 53% Grassland Herbaceous, 7% Deciduous Forest, and 0.14% Open Water. It was assumed that the area of Open Water was insignificant and excluded from our analysis.

LULC categories were combined in a similar fashion for the Kings Creek watershed. Emergent Herbaceous was added to the Grassland Herbaceous category. Mixed Forest was and Woody Wetlands were combined with Developed Forest forming the “Forest” category. Using these categories, Kings Creek watershed is comprised of 89% Grassland Herbaceous, 10%, and 1% Developed Open Space. LULC for Little Kitten Creek and Kings Creek watersheds are shown in Figures 3 and 4.

It was found that the watershed became more developed moving downstream. The Vanesta subwatershed, at the top of Little Kitten Creek watershed, is comprised of 20% Developed land. Kimball was comprised of 56%, and Anderson, the outlet of the watershed, comprised of 77% Developed land. Using this relationship, the outlet of each subwatershed was tested to determine if there was a similar relationship in water quality metrics. Figure 5 shows LULC percentage of total subwatershed area.

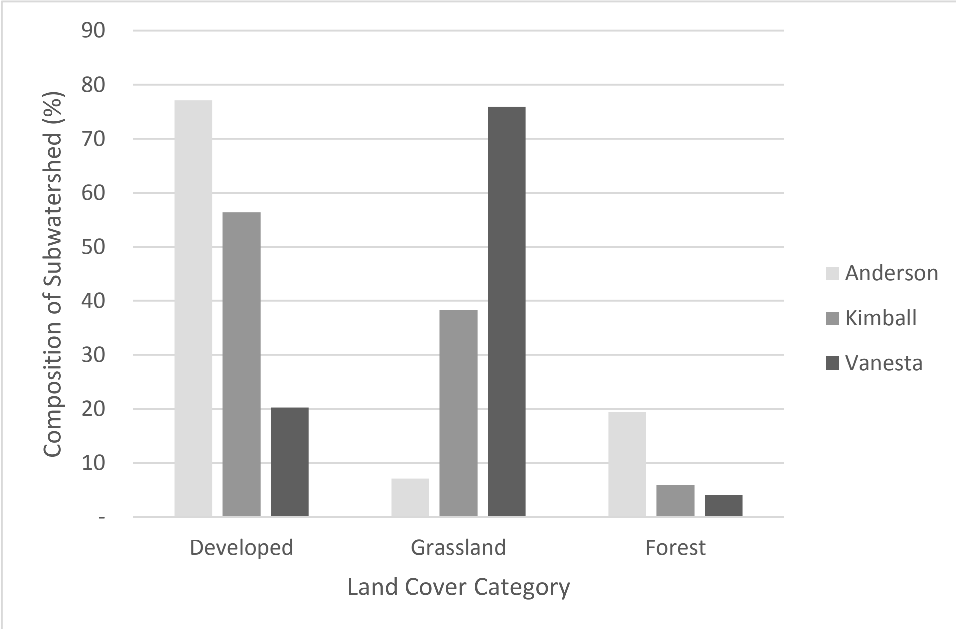

Figure 5: LULC Percent of Total Subwatershed Area

Sampling

Five samples were collected from each Little Kitten Creek test point, and two from Kings Creek, over a six week period from the end of October to beginning of December. The HACH® Surface Water Test kit (Fig. 6) was used to test samples on site. Tests include: air temperature, water temperature, pH, electrical conductivity (EC), dissolved oxygen (DO), nitrogen (N), phosphorus (P), and turbidity. The average of each result was computed. Averages of P, N and DO were compared between each subwatershed and Kings Creek. For the purpose of developing citizen science, testing was performed by non-expert, college students with the exception of one data set, assisted by a fourth grade students. Students had varying academic backgrounds, majoring in civil engineering,

Figure 6: HACH ® Test Kit

Limitations

With a sampling time period limited to six weeks, results do not show changes in water quality over time. It is assumed that the water quality of the Konza control watershed is similar to that of predevelopment conditions for Little Kitten Creek watershed. With a sampling period over a year the data might show more variability and give a better estimate of typical parameter values.

Another limitation of our data collection time was lack of precipitation. More runoff from significant rain events would carry pollutants from the surrounding land and provide a better understanding of the relationship between LULC and water quality. In addition, due to the lack of rainfall the test sites did not have a lot of water movement. As a result, the Vanesta watershed only had a small area of sitting water to test from.

The time of year was a limitation because there was a large amount of leaves and other debris in the water which could affect the water samples. Ice had to be broken to collect some samples which affect water properties and equipment accuracy. This was considered in the data analysis.

Results

Averages for each water quality parameter for each watershed are shown in Table 1. The comparison of average P, pH, EC, N, and DO concentrations between each subwatershed and Kings Creek is represented in Figure 7. No significant differences were observed between the test sites for pH and N levels. In addition, in comparison of the P, N and DO levels in the subwatersheds no significant difference was observed between the Vanesta, Anderson and Kimball subwatersheds. When compared to the control site at Kings Creek, the control showed significantly lower levels for the P, EC, and DO measurements. Levels of development in each individual watershed were also compared to the water quality indicators to determine if there were any significant correlations between water quality indicators and increasingly developed land. The only significant interaction observed was between percent developed land in a watershed and EC (Figure 8).

Watershed	DO (mg/L)	pH	P (mg/L)	N (mg/L)	EC (dS/m)
Vanesta	7.2	9.42	34.8	3	580.7
Anderson	6.8	9.34	33.6	2.2	863
Kimball	6.4	9.4	25.4	2.4	878.25
King's Creek	2	9.35	2.67	2	649.5

Table 1: Average Concentrations of Water Quality Indicators in Each Watershed

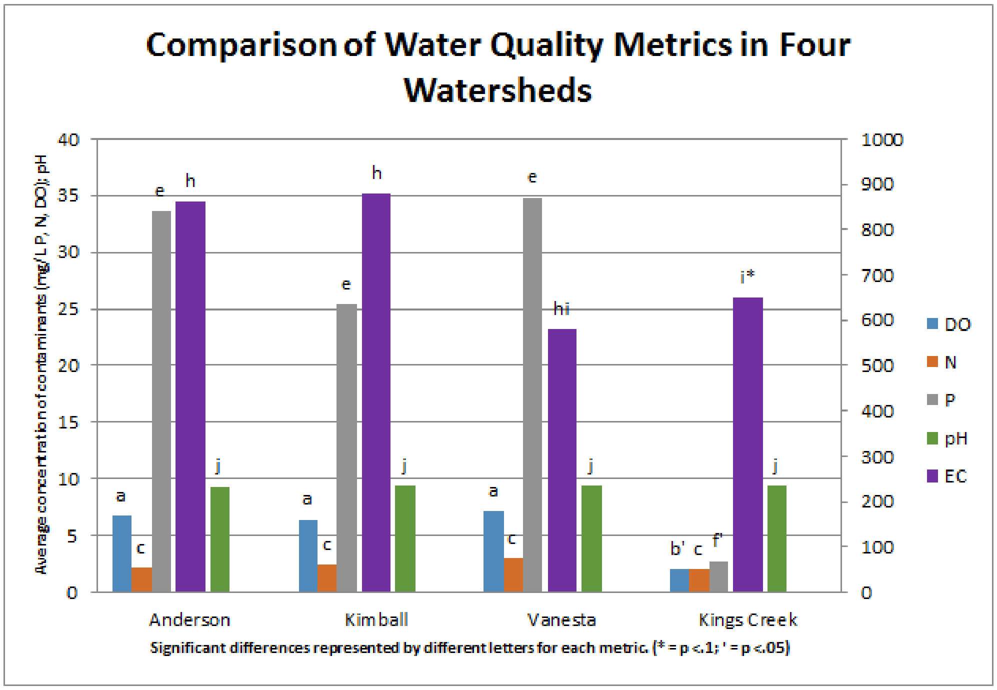

Figure 7: A Comparison of P, N, pH, DO, and EC for Little Kitten Creek Subwatersheds and Kings Creek Watershed

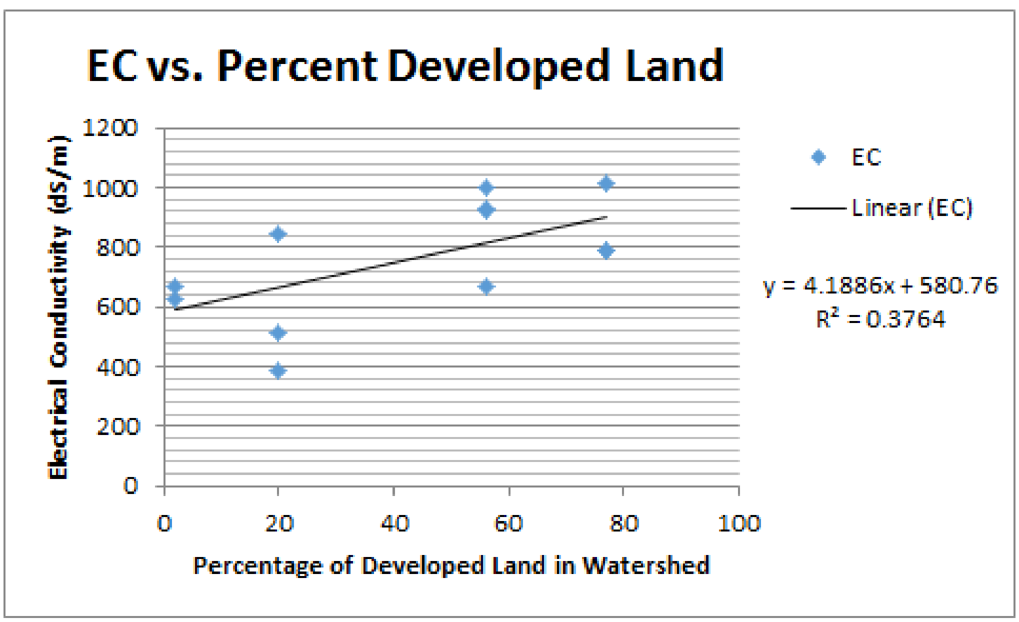

Figure 8: Correlation between Percent Developed Land and EC in Increasingly Urban Watershed

Conclusion and Discussion

The lower levels of dissolved oxygen were opposite of the predicted outcome. Areas that are rich in nitrogen and phosphorus typically begin to suffer from a condition called hypoxia which is characterized by low levels of oxygen. The opposite of this was observed in our study and could be due to sampling error. When sampling areas that have high nutrient levels, the upper section of surface waters may have higher oxygen levels as a result of increased algal activity, while below the water loses oxygen as microorganisms consume oxygen to break down algae. Because of this, it is important to get water samples from deep in the water.

The values of pH recorded over all of the samples were much higher than expected. This may have been due to an equipment error because all but one sample had a pH greater than 9. There were no significant differences between pH in any of the watersheds. The three sub-watersheds within the Little Kitten Creek watershed showed large differences in land use and land cover based on the LULC 2011 data provided by MRLC. In spite of these differences, no statistically significant differences were shown within the Anderson, Kimball and Vanesta watersheds for the water quality indicators. This could be due to various reasons. The Vanesta portion of the watershed has a large portion of land classified as natural land. However, this watershed drains much of Colbert Hills Golf Course which is classified as grassland. This could result in the three sub-watersheds having very similar nutrient levels as golf courses may contribute as much or more nutrients due to fertilization.

In contrast to the three sub-watersheds in the Little Kitten Creek watershed, the control watershed at King's Creek showed significantly lower levels of DO, and P. When compared to Anderson and Kimball, the control showed significantly lower levels of EC though no difference in EC was observed between the King's Creek watershed and the Vanesta watershed. Lower levels of EC are likely due to increased plant uptake of nutrients in the control watershed. Likewise, increased fertilization that occurs in suburban areas could be a contributing factor in the increased EC as well as P. Phosphorus over-fertilization is a significant global issue that results in high amounts of phosphorus in our watersheds. This trend is confirmed by the data collected in this experiment as all of our sub-watersheds show significantly higher P levels than the control watershed. This increased P level in developed watersheds is typically attributed to over-fertilization of lawns in suburban areas and increased soil erosion which are likely the cause of the increased phosphorus levels observed.

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